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Fractional derivative-based tracer analysis method for the characterization of mass transport in fractured geothermal reservoirs

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ABSTRACT

The fractional advection-dispersion equation (fADE) has been proposed to describe mass transport i
fractured reservoir. This study develops a finite discrete method to solve the fADE and tests its ac
racy against analytical solutions. Tracer simulation uses a three-dimensional simulation of flow analy
(FRACSIM-3D). The solution to the fADE incorporating a spatial fractional derivative shows reasona
agreement with the tracer response from FRACSIM-3D, which shows highly anomalous behaviors su
as a long tail. The prediction by the fADE model is reasonably similar to those of FRACSIM-3D irrespect
of differing well intervals.

1. Introduction

The lifespan of geothermal resources may be prolonged by a reinjection process, thereby delaying pressure decline and preventing run-out of water in a geothermal reservoir (Stefansson, 1997; Kaya et al., 2011; Axelsson et al., 2005). However, one of the important problems with reinjection is the possibility of an early thermal breakthrough in production wells. Premature breakthrough and injection-induced cooling continue to be problems associated with injection into the geothermal reservoir. Evaluation of the effect of injected water on flow and thermal properties within the geothermal reservoir is essential for the optimal management and protection of subsurface fluid resources.

Tracer testing is a standard method of determining mass transport within a geothermal reservoir and can be a valuable tool in the design and management of production and injection operations (Horne, 1985; Niibori et al., 1995; Pruess, 2002). Methods have also been discussed for predicting thermal breakthrough
fractured reservoirs based on information from tracer tests, e.g.,
Lauwerier (1955), Gringarten et al. (1975), Gringarten and Sa
(1975), Pruess and Bodvarsson (1984), and Kocabas (2005). Sh
(2001) discussed the potential application of tracer data to provi
relatively simple reservoir properties and to predict thermal bre
through. Such information could provide a means of optimiz
injection conditions and managing energy extraction (Wu et
2008). Furthermore, Lovekin and Horne (1989) and Juliusson a
Horne (2013) reported methods for optimizing injection schedu
in geothermal reservoirs based on tracer return data using num
ical simulations. In these cases, the production and injection we
were supposed to be already installed. The proposed method c
be advantageous to predict mass transport at a location witho
any wells; and, based on field tracer data obtained from a limit
number of wells, to determine where to optimally locate injecti
and/or production wells.

The inter-well properties provided by tracer tests are stron
controlled by the fracture geometries. Flow simulation mod
based on geological observation are often used to attempt quanti
tive assessment of tracer response curves. Discrete and continu
approaches form the two main branches in modeling the fluid fl
and solute transport in fractured rocks. Simulations using the d

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